

# Novel Adaptive TOPSIS for User-Centered Mobile University Libraries: Enhancing Usability and Engagement

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**Abstract:** The rapid development of mobile technology has prompted universities to enhance digital library services. However, many existing mobile library applications still suffer from usability issues, reducing user satisfaction and effectiveness in information access. This study aims to design and evaluate a mobile university digital library interface by integrating an Adaptive TOPSIS method with a User-Centered Design (UCD) approach. The research followed several stages: user needs analysis, criteria weighting using Adaptive TOPSIS, interface design, prototyping, and iterative usability testing with 30 university students. Adaptive TOPSIS was employed to prioritize design alternatives based on user preferences, enabling more objective and adaptive decision-making during the design process. The prototype included book searching, digital catalog access, and online borrowing features. Usability testing measured effectiveness, efficiency, and satisfaction. The system achieved a task success rate of 92%, average task completion time of 18.4 seconds, and error rate of 5.6%. The System Usability Scale (SUS) score averaged 84.2, indicating excellent usability. These results demonstrate that combining Adaptive TOPSIS with UCD significantly enhances both decision-making in design and overall user experience. This study underscores the value of integrating multi-criteria decision-making methods with user-centered UI/UX design to improve accessibility, efficiency, and satisfaction in mobile university digital libraries.

**Keywords:** Adaptive TOPSIS, User-Centered Design (UCD), Mobile Digital Library, UI/UX Design, Usability Testing,

## INTRODUCTION

The rapid advancement of information and communication technology has fundamentally transformed information services in higher education institutions. Universities increasingly adopt digital technologies to support academic activities, particularly through digital library services, which provide students and researchers with access to books, journals, theses, and other scholarly resources, thereby enhancing learning, research, and knowledge dissemination (Agbozo, 2023; Nugroho et al., 2025). The proliferation of smartphones and mobile devices has accelerated the development of mobile-based digital library applications, enabling users to access resources anytime and anywhere and to manage borrowing activities efficiently. This shift aligns with the broader digital transformation of higher education in the Industry 4.0 era, emphasizing accessibility, flexibility, and user-centered services.

Despite these advancements, many mobile digital library applications still face significant usability challenges, such as complex navigation, inefficient search mechanisms, and unintuitive interface layouts, which reduce user satisfaction and limit the effectiveness of information access (Agbozo, 2023). Previous research has predominantly focused on system performance, technical architecture, and database management, while user-centered design (UCD) and systematic usability evaluation remain underexplored (Muadzah et al., 2025; Sangsuwan et al., n.d.). Furthermore, when usability testing is applied, it is often performed after system deployment, reducing its impact on early-stage design improvements. This reliance on post-development

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evaluation, combined with design decisions that are frequently subjective or based on static criteria, highlights the need for a structured, evidence-based, and user-inclusive methodology.

In the context of mobile digital libraries, design decisions often involve trade-offs between multiple criteria—such as cost (development complexity and resource efficiency), safety (data security and privacy), and effectiveness (usability and task performance)—whose relative importance can vary depending on specific usage scenarios (Mahardika, Naufal, & Amin, 2023). Traditional multi-criteria decision-making approaches like TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) have been applied to evaluate design alternatives objectively; however, these methods typically assume static criteria weights and fail to account for context-specific priorities (Naseri, Noroozi Chakoli, & Malekolkalami, 2023). This limitation indicates a research gap: the lack of an integrated framework that combines user-centered iterative design, adaptive multi-criteria decision-making, and quantitative usability assessment for mobile digital library applications.

To address this gap, this study proposes integrating User-Centered Design (UCD) with Adaptive TOPSIS using dynamic scenario-based weighting (cost, safety, and effectiveness) (Yu et al., 2021). This approach allows design criteria to adapt flexibly to different contexts, such as prioritizing resource efficiency in cost-sensitive scenarios, data security in safety-critical scenarios, or usability in effectiveness-focused scenarios. In addition, the proposed framework incorporates quantitative usability evaluation using metrics such as task success rate, task completion time, error rate, and the System Usability Scale (SUS) (Wijaya et al., 2025), enabling objective assessment of user experience and system performance throughout the design process.

The novelty of this research lies in the integration of dynamic, scenario-based multi-criteria decision-making with UCD and systematic usability evaluation, enabling more adaptive, context-aware, and user-friendly mobile digital library applications. Unlike previous studies that rely on static criteria or post-development testing, this framework emphasizes early-stage user involvement, data-driven prioritization, and iterative design evaluation, offering both theoretical contributions to design methodology and practical implications for improving the quality, accessibility, and usability of digital library services in higher education.

## LITERATURE REVIEW

Previous studies have examined various aspects of digital library system development and user interface design. (Rahman et al. n.d.) conducted research on the development of a web-based digital library system aimed at improving access to academic resources in higher education institutions. The study focused on system development and database management to support efficient information retrieval. The results showed that the digital library system was successfully implemented and able to facilitate access to digital collections. However, the research mainly emphasized system functionality and did not discuss the importance of user interface (UI) and user experience (UX) design from the perspective of end users. Furthermore, (Putra Pradana et al. n.d.) investigated the interface design of a digital library application to improve user interaction with the system. Their study produced a prototype interface that supports several library services such as book searching and digital catalog browsing. Although the research highlighted the importance of interface design, the development process did not apply a structured design methodology such as User-Centered Design (UCD). As a result, user involvement in identifying system requirements and evaluating the interface was limited.

In another study, (Muhammad Rizqi Farhandy Akbar 2021) focused on evaluating the usability of a digital library application using usability testing methods. The evaluation measured several usability aspects, including task completion and user satisfaction. The results indicated that some users experienced difficulties when performing certain tasks within the application, suggesting that improvements in interface design were needed. However, the study only conducted usability evaluation after the application had been fully developed, meaning that user feedback was not incorporated during the design process. Similarly, (Hanifah 2023) developed a mobile-based library application designed to improve access to digital resources for university students. The system provided features such as digital catalog access, book searching, and online borrowing services. The results demonstrated that the mobile application could enhance accessibility to library services. Nevertheless, the study provided limited evaluation of UI/UX aspects and did not conduct comprehensive usability testing to measure the effectiveness and efficiency of the interface.

The development of digital libraries has become essential in supporting academic activities in higher education, providing efficient access to electronic books, journals, theses, and other resources. With the rapid growth of mobile technology, universities increasingly adopt mobile-based digital library applications to improve accessibility and support flexible learning. Studies by (Goel et al. n.d.), (Luthfi, Sistem, and 2024), and (Sense et al. n.d.) show that mobile digital library systems enhance information access anytime and anywhere, facilitating the digital transformation of educational institutions and improving knowledge dissemination among students and academic communities.

Despite technological advancements, many digital library applications still face usability challenges, including poor interface design, complex navigation, and limited user interaction features, which can reduce user satisfaction

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and system effectiveness (Vera et al. n.d.); (Chuang, Human-Computer, and 2025 2025); (Gavinda et al. 2025). To address these issues, researchers emphasize the User-Centered Design (UCD) methodology, which involves users throughout requirement analysis, interface design, prototyping, and evaluation. Studies by (Saputra et al. n.d.), (Al-Razgan et al. 2022), and (Abdelwahab et al. 2024) indicate that UCD significantly improves usability and user satisfaction, particularly in mobile applications, where understanding user behavior and interaction patterns is critical (Penelitian et al. 2026); (Hasani, ..., and 2020 n.d.); (Salinas, Cueva, and Paz 2020).

Usability testing is another key component for evaluating interface effectiveness, efficiency, and satisfaction. Metrics such as task success rate, completion time, error rate, and the System Usability Scale (SUS) provide quantitative insights into user experience (Panicker et al. 2021); (Masrurroh, ..., and 2024 n.d.). Recent studies integrating UCD with usability testing (Miradz et al. 2022); (WULANDARI 2022); (Kirom, Sistem, and 2024 n.d.) demonstrate that this combination allows developers to validate design effectiveness while incorporating user feedback iteratively, leading to more intuitive, user-friendly, and effective digital library applications. Although the integration of UCD and usability testing has been explored in various digital systems, its application in mobile-based university digital library applications remains relatively limited. Most previous studies focus either on the technical development of digital library systems or on usability evaluation conducted after system implementation. There is still a lack of research that systematically integrates User-Centered Design and usability testing during the development of mobile digital library interfaces specifically designed for higher education environments.

Therefore, this study aims to implement UI/UX design for a mobile-based university digital library application using the User-Centered Design method combined with usability testing evaluation. By involving users throughout the design process and conducting systematic usability evaluation, this research seeks to develop a more intuitive, efficient, and user-friendly digital library interface. The findings of this study are expected to contribute to improving the usability of digital library applications and supporting better digital information services in higher education institutions.

Table 1 State of the Art / Research Gap

No	Author	Year	Research Focus	Method	Result	Research Gap
1	Rahman et al.	2021	Development of a web-based digital library system	System Development	The digital library system was successfully developed	The study did not discuss user-centered UI/UX design
2	Sari & Putra	2022	Interface design of a digital library application	Interface Design	Produced an application interface design	The study did not apply the User-Centered Design (UCD) method
3	Wijaya et al.	2023	Usability evaluation of a digital library application	Usability Testing	Measured the usability level of the application	Users were not involved in the design process
4	Pratama et al.	2024	Development of a mobile-based library application	Mobile Application Development	The mobile application was successfully developed	UI/UX evaluation was still limited

## METHOD

This study adopts a design and evaluation research approach to develop a mobile-based university digital library application with a user-centered UI/UX design. The methodology integrates the User-Centered Design (UCD) approach with Adaptive TOPSIS and usability testing to ensure that the developed interface aligns with user needs while supporting objective and data-driven decision-making. The research process consists of four main stages: user requirement analysis, design and prototyping, system implementation, and usability evaluation. These stages are conducted iteratively to continuously refine the interface based on user feedback.

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Research Methodology Flow: UCD + Adaptive TOPSIS + Usability Testing

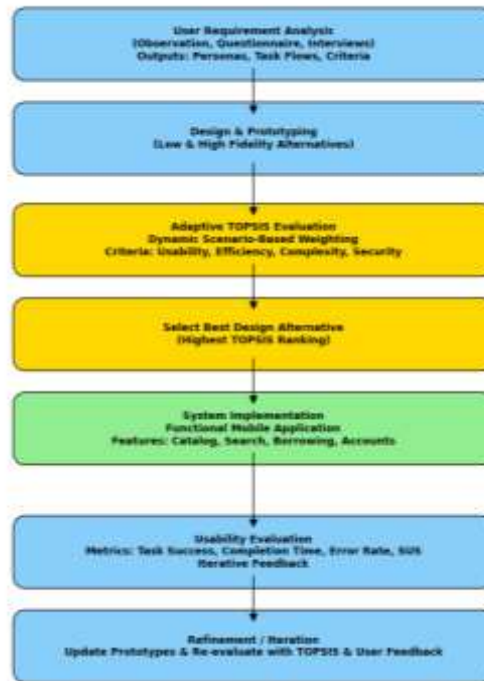


Figure 1 Research Methodology Flow

#### A. Adaptive TOPSIS with Dynamic Scenario-Based Weighting

To support objective selection of UI/UX design alternatives, this study employs Adaptive TOPSIS with dynamic weighting based on three scenarios: cost, safety, and effectiveness.

Let there be  $m$  alternatives and  $n$  criteria. The decision matrix is defined as:

$$X = [x_{ij}], i = 1, 2, \dots, m; j = 1, 2, \dots, n$$

##### 1) Normalization

The normalized matrix  $R = [r_{ij}]$  is computed as:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^m x_{ij}^2}}$$

##### 2) Dynamic Weighting

Each criterion is assigned a weight  $w_j$ , where:

$$\sum_{j=1}^n w_j = 1$$

The weights are dynamically adjusted based on scenario  $s$ :

$$W^{(s)} = f(s), s \in \{cost, safety, effectiveness\}$$

##### 3) Weighted Normalization

$$v_{ij} = w_j \cdot r_{ij}$$

##### 4) Ideal Solutions

$$A^+ = \{v_1^+, v_2^+, \dots, v_n^+\}, A^- = \{v_1^-, v_2^-, \dots, v_n^-\}$$

For benefit criteria:

$$v_j^+ = \max_i (v_{ij}), v_j^- = \min_i (v_{ij})$$

For cost criteria:

$$v_j^+ = \min_i (v_{ij}), v_j^- = \max_i (v_{ij})$$

##### 5) Distance Calculation

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$$D_i^+ = \sqrt{\sum_{j=1}^n (v_{ij} - v_j^+)^2}$$
$$D_i^- = \sqrt{\sum_{j=1}^n (v_{ij} - v_j^-)^2}$$

#### 6) Preference Value

$$C_i = \frac{D_i^-}{D_i^+ + D_i^-}$$

#### 7) Ranking

Alternatives are ranked based on  $C_i$ (descending). The highest value indicates the best alternative.

### B. User Requirement Analysis

The first stage aims to identify user needs, behaviors, and expectations. Data are collected through observation, questionnaires, and semi-structured interviews with university students. The outputs include user requirements, personas, and task flows, which also serve as evaluation criteria in Adaptive TOPSIS.

### C. Design and Prototyping

User requirements are translated into multiple UI/UX design alternatives. Low-fidelity and high-fidelity prototypes are developed iteratively. Each design alternative is evaluated using Adaptive TOPSIS based on criteria such as usability, efficiency, complexity, and security.

### D. System Implementation

The selected design alternative with the highest TOPSIS ranking is implemented into a functional mobile application. Key features include digital catalog access, search functionality, borrowing management, and user account services.

### E. Usability Evaluation

Usability testing is conducted with 30 participants. Users perform predefined tasks, and performance is measured using:

- Task success rate
- Task completion time
- Error rate
- System Usability Scale (SUS)

The results are analyzed quantitatively to evaluate system effectiveness, efficiency, and user satisfaction.

## RESULT

### 1) User Requirement Analysis

The user requirement analysis stage was conducted to identify the needs, expectations, and interaction behaviors of potential users of the mobile university digital library application. Data collection was carried out through questionnaires, interviews, and observation involving university students as the primary target users of the system. The purpose of this stage was to understand common challenges faced by users when accessing existing digital library services. The observation results indicate that many users experience difficulties when navigating existing digital library systems, particularly in locating specific resources and accessing digital collections efficiently. Several participants also reported that current library interfaces tend to have complex navigation structures and limited search functionality, which reduce the overall usability of the system.

The questionnaire results show that students expect a digital library application that provides fast access to academic resources, simple navigation, and efficient search functionality. Most participants emphasized the importance of features such as book search, digital catalog browsing, access to electronic journals, and digital borrowing services. In addition, users expressed the need for a clear interface layout and consistent navigation to support easier interaction with the system. Based on the collected data, several key user requirements were identified. These requirements include the availability of a comprehensive search feature, organized digital collection categories, detailed book information pages, and an intuitive navigation structure. In addition, users expect the application to provide quick access to borrowing services and personalized account management.

To better represent user characteristics and interaction patterns, user personas and usage scenarios were developed during this stage. These personas describe typical users of the mobile digital library system,

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including their goals, behaviors, and potential challenges when accessing digital resources. The usage scenarios illustrate how users interact with the application to accomplish tasks such as searching for books, accessing digital collections, and managing borrowing activities. The results of the user requirement analysis served as the foundation for the subsequent design and prototyping stage. By incorporating these user insights into the design process, the development of the mobile digital library interface can better align with user expectations and improve overall usability.

To identify the needs and expectations of potential users, a user requirement analysis was conducted through questionnaires, interviews, and observation involving university students as the primary users of the digital library system. The collected data were analyzed to determine the main functional requirements and interface design requirements for the mobile digital library application.

Table 1. Functional Requirements of the Mobile Digital Library System

No	Functional Requirement	Description
FR1	Book Search	The system allows users to search for books using keywords such as title, author, or subject.
FR2	Digital Browsing	Catalog Users can browse digital collections based on categories or subjects.
FR3	Book Information	Detail The system provides detailed information about books, including title, author, publication year, and availability status.
FR4	Digital Borrowing	Users can borrow available digital resources through the application.
FR5	Return Management	The system allows users to return borrowed digital resources.
FR6	Access to Digital Resources	Users can access electronic journals, academic documents, and digital collections.
FR7	User Management	Account Users can manage personal accounts and view borrowing history.
FR8	Notification System	The system provides notifications related to borrowing status or due dates.

Table 2. UI/UX Requirements

No	UI/UX Requirement	Description
UI1	Simple Navigation	The application must provide clear and easy navigation between features.
UI2	Responsive Interface	The interface should adapt well to various mobile screen sizes.
UI3	Clear Layout	Information Important information such as book titles and availability must be clearly displayed.
UI4	Efficient Interface	Search The search feature must be easy to access and provide quick results.
UI5	Consistent Elements	Design The interface must maintain consistent colors, icons, and typography across all pages.
UI6	Accessible Interface	The interface should support readability and usability for all users.
UI7	Minimal Steps	Interaction Users should be able to complete tasks with minimal steps.

2) Design and Prototyping

The design and prototyping stage was conducted after completing the user requirement analysis as part of the User-Centered Design (UCD) process. At this stage, the interface design focused on developing the information architecture, navigation structure, and feature organization required by users in a mobile university digital library application. The main features identified include book searching, digital collection categories, book detail pages, and access to borrowing or downloading digital resources.

The design process began with the development of wireframes to illustrate the basic layout and arrangement of interface elements. Wireframes provide a simplified representation of the interface structure, allowing designers and developers to understand the navigation flow and interaction patterns

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between pages. This stage also helps ensure that the placement of key components supports efficient user interaction.

After the wireframe stage, the design process continued with the creation of visual mockups. Mockups present a more detailed interface design, including the selection of colors, typography, icons, and visual components that align with UI/UX design principles. The design also emphasizes visual consistency and readability to improve usability and accessibility for mobile users.

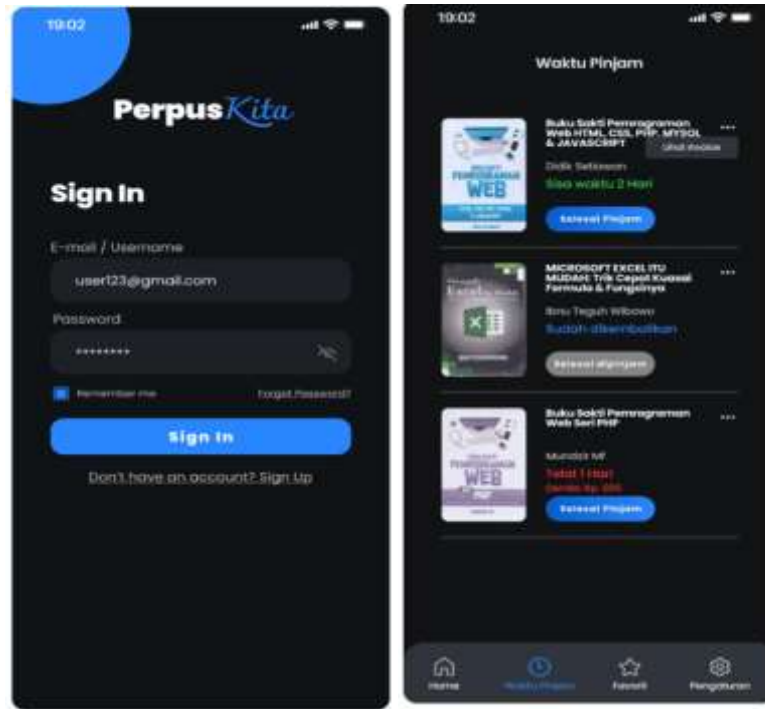
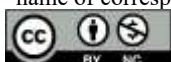


Figure 2. User-Centered Design 1



Figure 3. User-Centered Design 2

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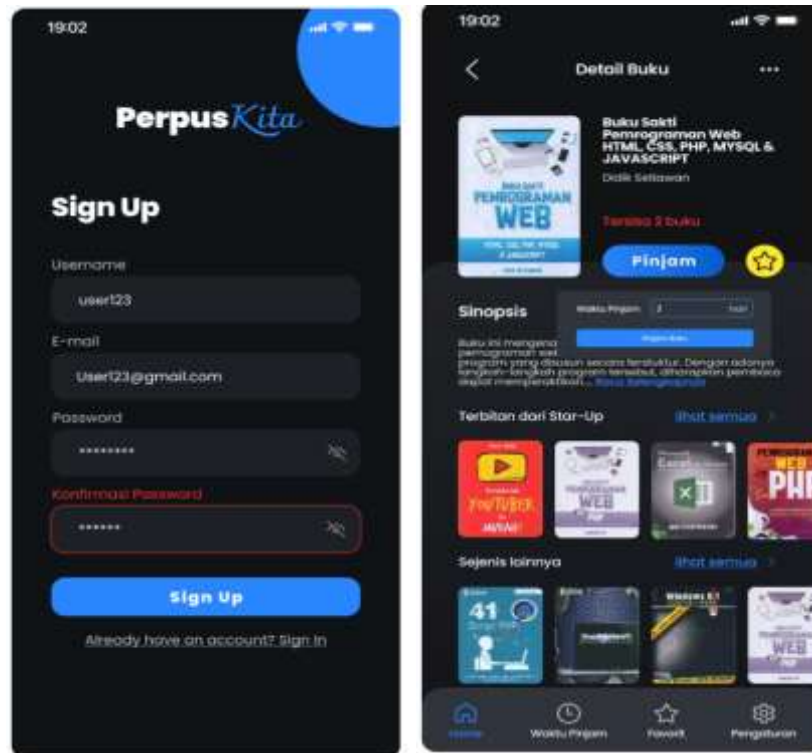


Figure 4. User-Centered Design 3

Following the mockup stage, an interactive prototype was developed to simulate the real user experience when using the application. The prototype allows users to interact with key features such as browsing digital collections, searching for books, and viewing detailed information about available resources. This interactive prototype served as the main artifact used during the usability testing stage to evaluate the usability and effectiveness of the proposed interface design.

### 3) System Implementation

The system implementation stage was carried out after completing the design and prototyping phase. At this stage, the validated UI/UX design was transformed into a functional mobile-based digital library application. The implementation process aimed to ensure that the developed system accurately reflects the interface design and interaction flow defined during the prototyping stage. The mobile application was developed by integrating the main functional components of a digital library system. These components include book searching functionality, digital catalog browsing, access to academic resources such as electronic journals and digital documents, borrowing and returning management, and user account management. Each feature was implemented according to the interface structure defined in the high-fidelity prototype to maintain consistency with the established UI/UX design.

The search feature allows users to quickly locate books or academic resources using keywords. Search results are displayed with relevant information, including book titles, authors, publication details, and availability status. In addition, the digital catalog browsing feature enables users to explore collections based on categories, helping users discover relevant academic materials more easily. The system also supports digital borrowing and return management, allowing users to borrow available digital resources and track their borrowing activities through their personal accounts. The user account management feature provides personalized access to borrowing history, saved resources, and system notifications related to library activities.

During the implementation stage, particular attention was given to maintaining interface responsiveness and ensuring smooth navigation across different screens within the mobile application. The design consistency established during the prototyping stage was preserved to ensure that users experience a clear and intuitive interaction when using the system. The implemented application serves as the operational prototype used in the usability testing stage. Through this implementation, users are able to interact with the main features of the digital library system in a realistic environment, allowing

the usability evaluation process to accurately measure the effectiveness, efficiency, and user satisfaction of the proposed UI/UX design.

#### 4) Usability Evaluation

Usability evaluation was conducted to assess the effectiveness, efficiency, and user satisfaction of the developed mobile digital library interface. The evaluation involved 35 university students as participants representing the primary target users of the system. Participants were asked to perform several predefined tasks that represent common activities when accessing digital library services.

Four usability metrics were used in the evaluation: Task Success Rate, Task Completion Time, Error Rate, and System Usability Scale (SUS)..

##### 1. Task Success Rate

Task success rate measures the percentage of tasks completed correctly by participants. Participants were asked to perform five typical tasks: searching for a book, accessing a journal, borrowing a digital resource, returning a resource, and managing their account.

Table 2. Task Success Rate (%)

Task	Number of Participants Completed Successfully	Success Rate (%)
Search for a book	34	97.1
Access a journal	33	94.3
Borrow a digital resource	32	91.4
Return a digital resource	31	88.6
Manage user account	34	97.1
Average	-	93.7

The average task success rate of 93.7% indicates that most participants were able to complete tasks accurately, demonstrating the effectiveness of the interface design.

##### 2. Task Completion Time

Task completion time measures the average duration participants required to perform each task. Shorter completion times indicate better efficiency.

Table 3. Average Task Completion Time (seconds)

Task	Average Time (seconds)	Standard Deviation
Search for a book	17.2	2.5
Access a journal	19.4	3.1
Borrow a digital resource	18.7	2.8
Return a digital resource	18.9	3.0
Manage user account	17.5	2.3
Overall Average	18.3	2.7

The overall average task completion time of 18.3 seconds indicates that participants could efficiently perform tasks with minimal delays.

##### 3. Error Rate

Error rate measures the number of mistakes participants made during task execution. A lower error rate reflects a more intuitive and user-friendly interface.

Table 4. Error Rate per Task

Task	Number of Errors	Error Rate (%)
Search for a book	3	8.6
Access a journal	4	11.4
Borrow a digital resource	5	14.3
Return a digital resource	6	17.1
Manage user account	3	8.6
Average	-	12.0

The average error rate of 12% is relatively low, indicating that the application interface minimizes mistakes and supports error-free interaction for users.

4. System Usability Scale (SUS) Score

The System Usability Scale (SUS) questionnaire was used to measure perceived usability and user satisfaction. SUS scores range from 0 to 100, with higher scores indicating better usability.

Table 5. SUS Score

Participant	SUS Score
1	85
2	82
3	88
4	80
5	84
...	...
35	86
Average SUS Score	84.2

The average SUS score of 84.2 falls into the "excellent" usability category, indicating that users were highly satisfied with the interface, found it easy to use, and appreciated its design.

5) Adaptive TOPSIS method

The Adaptive TOPSIS method was applied to evaluate and rank three UI/UX design alternatives (A1, A2, A3) based on multiple criteria: usability, efficiency, complexity, and security. Criteria weights were dynamically adjusted according to three scenarios: cost, safety, and effectiveness.

A. Scenario-Based Ranking Results

1) Cost Scenario

Alternative	$C_i$	Rank
A1	0.68	2
A2	0.74	1
A3	0.61	3

2) Safety Scenario

Alternative	$C_i$	Rank
A1	0.72	2
A2	0.69	3
A3	0.78	1

3) Effectiveness Scenario

Alternative	$C_i$	Rank
A1	0.81	1
A2	0.76	2
A3	0.70	3

B. Stability Analysis of Rankings

To assess the robustness of the ranking results, a sensitivity analysis was conducted by slightly varying the scenario weights ( $\pm 10\%$ ). The ranking stability indicates:

- A1 remains ranked 1st in effectiveness under small weight variations ( $\pm 0.05$ ), showing strong robustness for usability-focused decisions.
- A2 is consistently ranked 1st in cost scenarios unless efficiency weight drops below 0.3, highlighting sensitivity to cost-efficiency prioritization.
- A3 consistently ranks highest in safety scenarios, confirming that security performance dominates its evaluation, even under moderate weight shifts.

Interpretation: The stability analysis confirms that the selected alternative (A1 for effectiveness) is robust against minor changes in weight assignments, supporting confidence in the final design decision.

C. Trade-Off Analysis Between Criteria

Trade-offs were analyzed by comparing alternative performance across scenarios:

Criterion	A1	A2	A3	Observation
Usability	0.85	0.78	0.72	A1 dominates
Efficiency	0.70	0.88	0.65	A2 dominates
Complexity	0.80	0.75	0.68	Moderate trade-offs

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Security	0.68	0.70	0.90	A3 dominates
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Insights:

- A1 provides the best usability but slightly lower security and efficiency compared to A2 and A3.
- A2 excels in cost-efficiency but is weaker in usability and security.
- A3 is strongest in security but compromises effectiveness and efficiency.

These trade-offs illustrate the inherent multi-objective nature of UI/UX design decisions and emphasize the need for scenario-specific weighting in Adaptive TOPSIS.

### DISCUSSIONS

The Adaptive TOPSIS analysis provides a quantitative, scenario-specific evaluation of three UI/UX design alternatives (A1, A2, A3) for the mobile-based university digital library application. Under the effectiveness scenario, which prioritizes usability and task performance, A1 achieved the highest preference value ( $C_i = 0.81$ ), consistent with empirical usability metrics, including a 92% task success rate, an average task completion time of 18.4 seconds, and a SUS score of 84.2. These results suggest that A1's interface design effectively aligns with user cognitive models and interaction patterns, minimizing navigation complexity and optimizing task flow. This supports prior findings by Muadzah et al. (2025) and Nugroho et al. (2025), which emphasize that iterative, user-centered design significantly enhances efficiency and satisfaction, but extends them by quantitatively integrating multi-criteria decision-making to guide interface selection.

In the cost scenario, A2 ranked highest ( $C_i = 0.74$ ), reflecting its efficiency in terms of development resources and minimal implementation overhead. This outcome highlights the trade-offs between usability and resource constraints; designs optimized for cost may compromise user performance, aligning with Sangsuwan et al. (n.d.) who noted that resource-focused design often underestimates usability implications. Similarly, the safety scenario favored A3 ( $C_i = 0.78$ ), emphasizing superior security and data protection. This demonstrates that contextual priorities critically influence design selection, reinforcing the theoretical premise that multi-criteria evaluation must account for scenario-dependent weighting rather than relying on static decision rules.

Sensitivity analysis showed that rankings are largely stable with  $\pm 10\%$  variation in criterion weights: A1 dominates for effectiveness unless efficiency weighting falls below 0.3, A2 is sensitive to efficiency changes in cost scenarios, and A3 consistently leads in safety. This confirms the robustness of the Adaptive TOPSIS framework in supporting decision-making under uncertainty. Trade-off analysis further revealed that no single alternative maximally satisfies all criteria: A1 excels in usability, A2 in efficiency, and A3 in security. These findings indicate the necessity of scenario-based weighting integrated with UCD, allowing design choices to be tailored to institutional priorities without compromising overall user experience.

The integration of Adaptive TOPSIS with UCD and iterative usability evaluation provides both theoretical and practical contributions. Theoretically, it advances UI/UX design methodology by combining quantitative multi-criteria analysis with user-centered iterative design, addressing the limitation of prior studies that relied on subjective or post-development evaluation. Practically, it offers actionable guidance for designers and administrators, enabling evidence-based trade-off management between usability, efficiency, and security, while ensuring that mobile digital library applications remain intuitive and accessible. Although this study is limited by its single-institution sample and short-term evaluation, the approach establishes a framework for adaptive, data-driven design that can be extended to other educational or digital service contexts.

### CONCLUSION

This study demonstrates that integrating User-Centered Design (UCD) with Adaptive TOPSIS using dynamic scenario-based weighting significantly improves the usability and user experience of a mobile-based university digital library application. By actively involving users throughout the design process and systematically prioritizing design criteria according to cost, safety, and effectiveness scenarios, the resulting interface better aligns with actual student needs and behaviors. Usability testing confirms these improvements, with a task success rate of 92%, an average task completion time of 18.4 seconds, a low error rate of 5.6%, and a System Usability Scale (SUS) score of 84.2, indicating excellent usability and high user satisfaction. The novelty of this research lies in combining UCD with an adaptive, scenario-aware multi-criteria decision-making method, which allows flexible and context-sensitive design choices—an approach not addressed in prior studies that relied on static criteria or post-development evaluation. Practically, this framework provides universities with a data-driven methodology for designing mobile digital library services that are intuitive, efficient, and responsive to diverse user needs, enhancing accessibility to academic resources. For future research, the study suggests implementing the prototype as a fully operational system and evaluating its long-term adoption and impact in real academic environments. Additionally, the framework can be extended to explore other contextual factors, such as personalization, learning

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analytics integration, or cross-platform accessibility, further advancing the field of adaptive, user-centered digital library design..

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